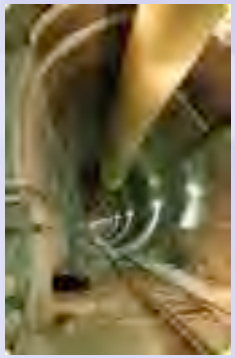


Semantic Building Blocks for 21st Century Building Engineering

Lawrence Berkeley National Laboratory

October 2, 2009

Mark Palmer

Leader, Computer Integrated Building Processes Group
Building and Fire Research Laboratory
National Institute of Standards and Technology

Outline

- Introduce NIST and BFRL
- Challenges of transitioning construction to model-driven integrated design and delivery
- Semantic foundation for collaborative management of virtual models
- Collaborative project to develop and test Reference Information Models for:
  - building envelop, thermal model, HVAC systems, equipment and project QC

NIST At A Glance

Gaithersburg, MD

Boulder, CO

- NIST Research Laboratories
- Baldrige National Quality Award
- Manufacturing Extension Partnership
- Technology Innovation Program

- **~ 2,900 employees**
- **~ 2,600 associates and facility users**
- **~ 1,600 field staff in partner organizations**
- **~ 400 NIST staff serving on 1,000 national and international standards committees**

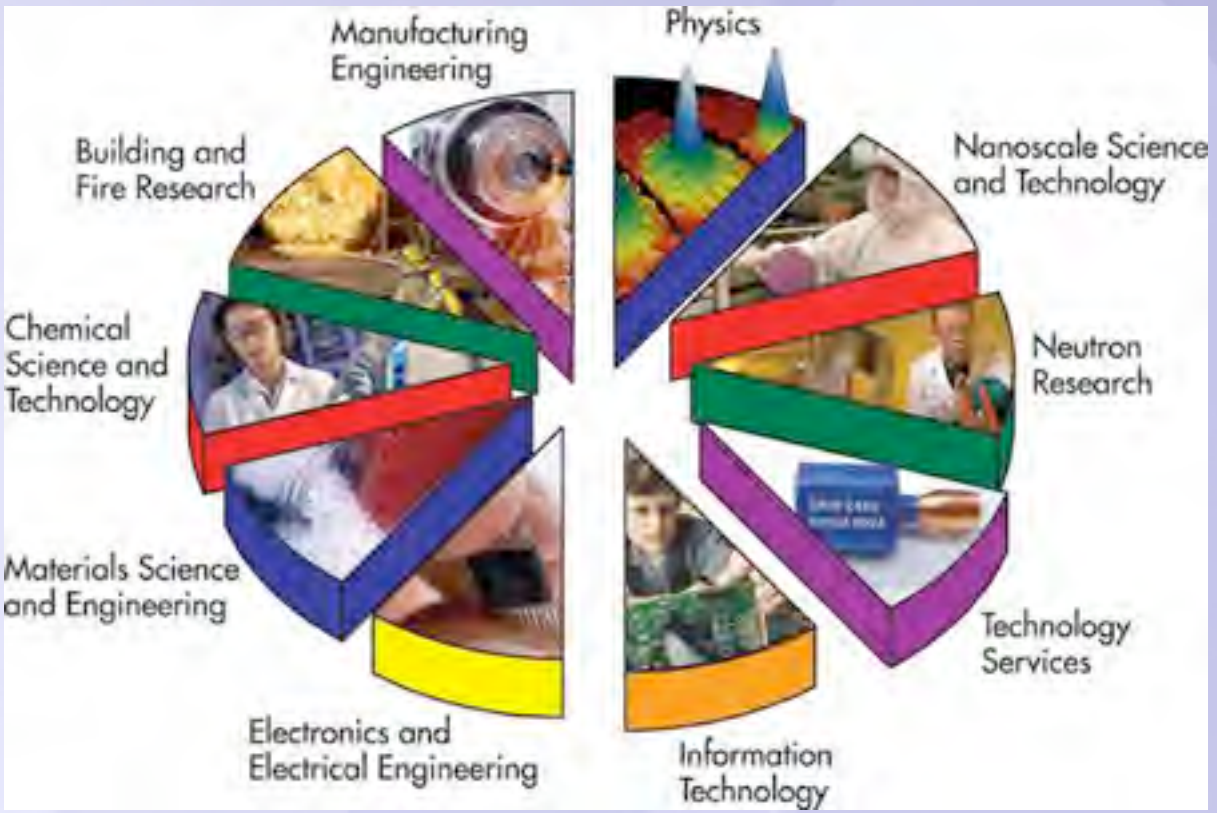
The NIST Laboratories

NIST's work enables

- **Advancing manufacturing and services**
- **Helping ensure fair trade**
- **Improving public safety and security**
- **Improving quality of life**

NIST works with

- **Industry**
- **Academia**
- **Other agencies**
- **Government agencies**
- **Measurement laboratories**
- **Standards organizations**



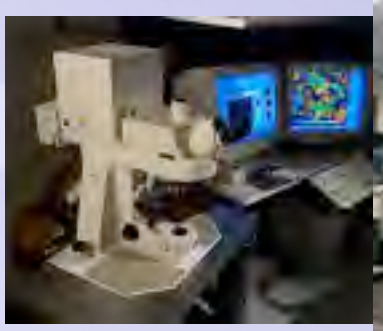
BFRL Mission

To promote U.S. *innovation* and *competitiveness* by anticipating and meeting the:

- **measurement science,**
- **standards, and**
- **technology**

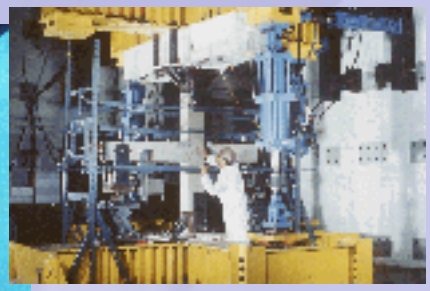
needs of the U.S. building and fire safety industries in ways that enhance *economic security* and improve the *quality of life.*

Measurement Science



Virtual Cement and Concrete Testing Laboratory

Integrating Sphere for Service Life Prediction of Materials



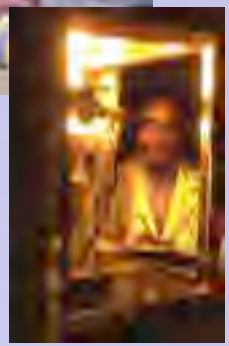
Tri-directional Test Facility

Large-Scale Structures Testing Laboratory

Construction Site Metrology

Residential Fuel Cell Testing Laboratory

High Temperature Guarded Hot Plate for Advanced Thermal Insulation Measurements



Large Fire Research Facility

Cone Calorimeter

Scope of Measurement Science

The term ***measurement science*** includes:

- the development of performance metrics, measurement methods, predictive tools, and protocols as well as reference materials, data, and artifacts
- the conduct of inter-comparison studies and calibrations
- the evaluation and/or assessment of technologies, systems, and practices
- the development and/or dissemination of technical guidelines and basis for standards, codes, and practices—in many instances via testbeds, consortia, and/or other partnerships with the private sector

Other Agency Partners

Federal R&D Agenda for Net-Zero Energy, High-Performance Green Buildings

Goal 1: Develop enabling measurement science

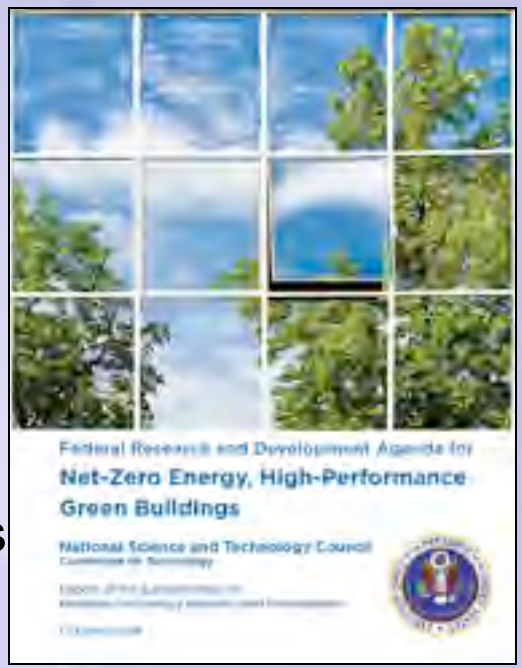
Goal 2: Develop NZEB building technologies and strategies

Goal 3: Develop scientific and technical basis for significant water use reduction

Goal 4: Develop processes, protocols and products for building materials that minimize waste and impact

Goal 5: Develop knowledge, technologies and practices to promote occupant health, comfort and productivity

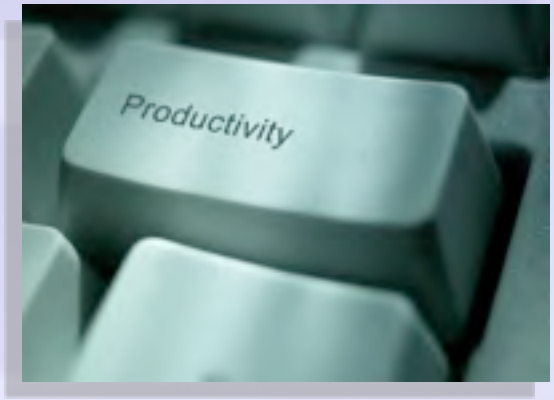
Goal 6: Enable technology transfer for net-zero energy, high-performance buildings



Key *Drivers* for Change in Construction

- Energy independence, environmental security, and sustainability
- Renewal of Nation's aging physical infrastructure
- Demand for better quality, faster, and less costly construction
- Competition due to globalization and offshoring
- Homeland security and disaster resilience

Key *Barriers* to Change in Construction



- Waste, inefficiency and industry fragmentation
- Minimum first-cost mindset precludes lower-cost investment options based on life-cycle performance
- Prescriptive standards and codes stifle innovation and competitiveness
- Low profit margins and R&D investment

NIST Partnerships with the Construction Industry

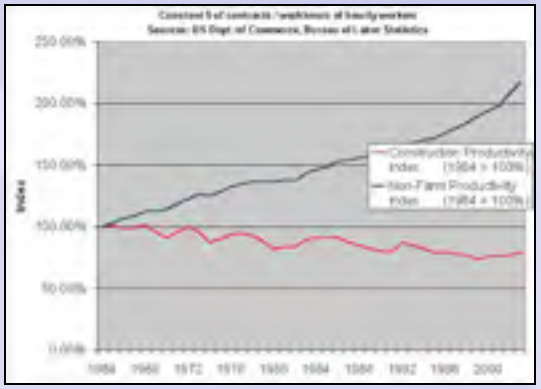
- Board of Advisors
- Breakthrough Strategy Committee
- Research Committee
- Benchmarking and Metrics Committee
- Workshops and Conferences
- Research Teams

(Conceived by CII and NIST in 1999)

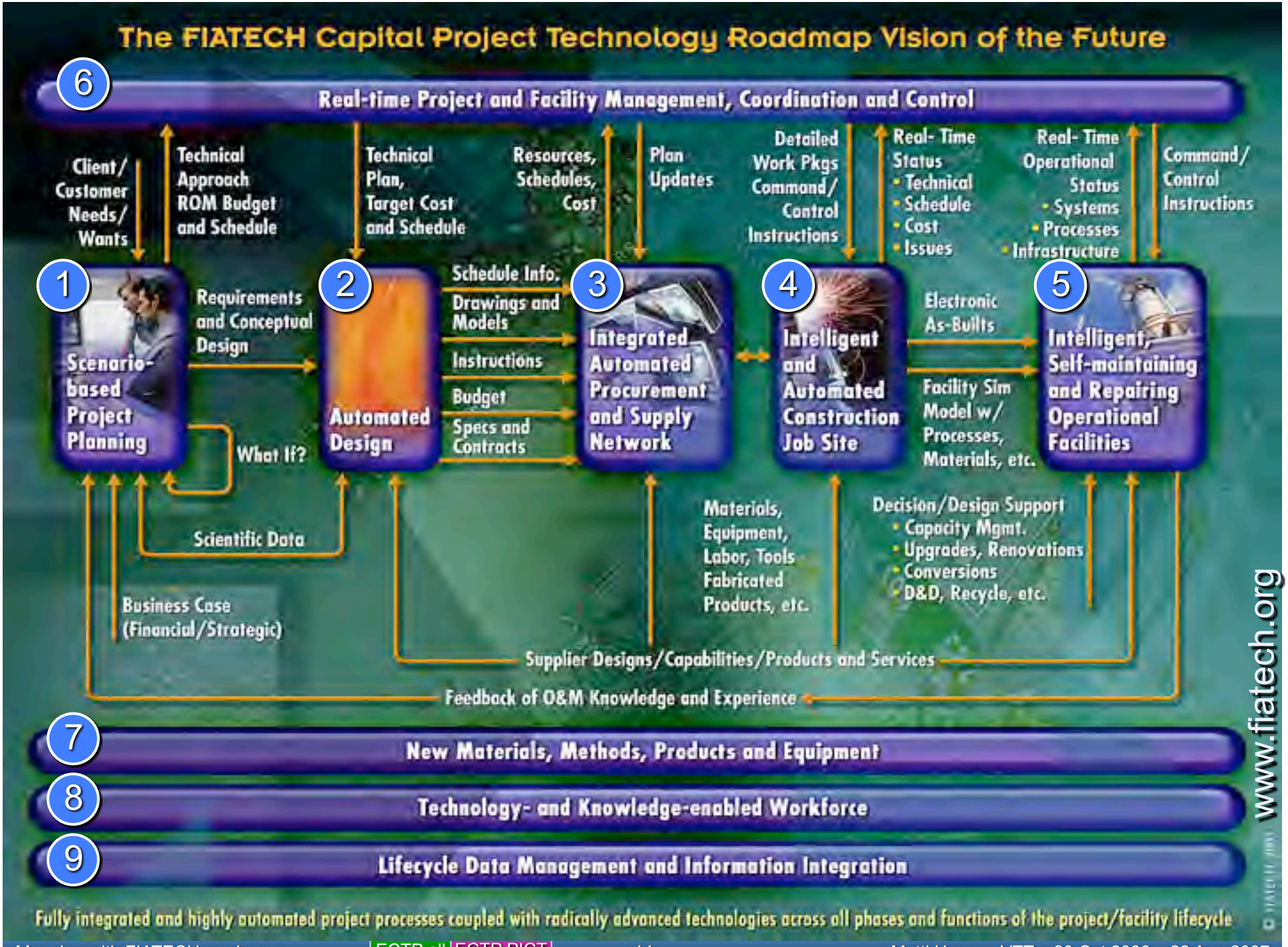
- Capital Projects Technology Roadmap
- Automating Equipment Information Exchange
- Intelligent and Automated Construction Job Site
- Plant and Building Information Modeling
- Workshops and Conferences

- Building and Fire Codes and Standards
- Technical Guidelines
- Measurement Techniques
- Performance Prediction Tools
- Committees, Councils, and Boards
- Workshops and Conferences
- Collaborative Research
- Publications
- Working Groups

Productivity-Driven Challenges



- **Lack of effective performance measures**
  - **some report 40-yr decline in construction productivity (-0.6% per year); Increase in non-farm productivity (+1.8% per year)**
  - **significant improvement in some work processes**
- **25-50% *waste and inefficiencies* in labor & material control**
- **$17- 36 B/yr cost of *inadequate interoperability***
  - **in commercial and industrial construction alone**
- **Projected $2 trillion cost-burden for infrastructure renewal**
- **Increasing *global competition*: 160% increase in Chinese contracts in U.S. and Europe during 2007**
- **Measurement science is lacking to measure impact of inefficient construction, new technologies and processes**
- **NIST requested National Research Council to establish a panel to:**
  - *identify and prioritize **technologies, processes and deployment activities** with greatest potential to advance significantly productivity and competitiveness of the capital facilities sector*
  - ***Advancing the Competitiveness and Efficiency of the U.S. Construction Industry** (October 2009)*


The FIATECH Capital Project Technology Roadmap Vision of the Future
6
Real-time Project and Facility Management, Coordination and Control
Client/ Customer Needs/ Wants
Technical Approach ROM Budget and Schedule
Technical Plan, Target Cost and Schedule
Resources, Schedules, Cost
Plan Updates
Detailed Work Pkgs Command/ Control Instructions
Real- Time Status • Technical • Schedule • Cost • Issues
Real- Time Operational Status • Systems • Processes • Infrastructure
Command/ Control Instructions
1
Scenario-based Project Planning
Requirements and Conceptual Design
What If?
2
Automated Design
Schedule Info.
Drawings and Models
Instructions
Budget
Specs and Contracts
3
Integrated Automated Procurement and Supply Network
4
Intelligent and Automated Construction Job Site
Electronic As-Builts
Facility Sim Model w/ Processes, Materials, etc.
5
Intelligent, Self-maintaining and Repairing Operational Facilities
Scientific Data
Business Case (Financial/Strategic)
Materials, Equipment, Labor, Tools Fabricated Products, etc.
Decision/Design Support • Capacity Mgmt. • Upgrades, Renovations • Conversions • D&D, Recycle, etc.
Supplier Designs/Capabilities/Products and Services
Feedback of O&M Knowledge and Experience
7
New Materials, Methods, Products and Equipment
8
Technology- and Knowledge-enabled Workforce
9
Lifecycle Data Management and Information Integration
Fully integrated and highly automated project processes coupled with radically advanced technologies across all phases and functions of the project/facility lifecycle
www.fiatech.org

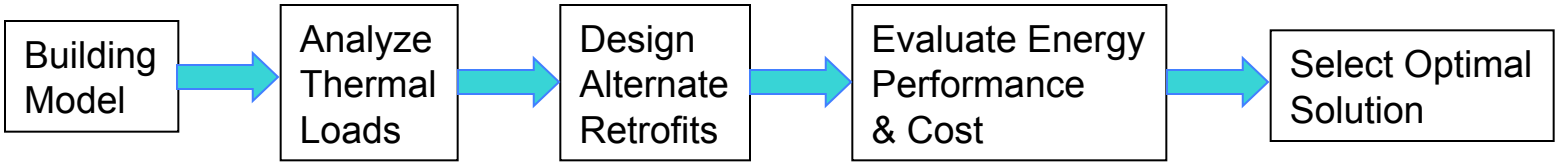
BFRL Strategic Priorities

Measurement Science for:

- ➢ *Net Zero Energy, High-Performance Buildings*
- Advancing Infrastructure Delivery
- Predicting Life Cycle Performance of Infrastructure Materials
- Innovative Fire Protection
- Disaster-Resilient Structures and Communities

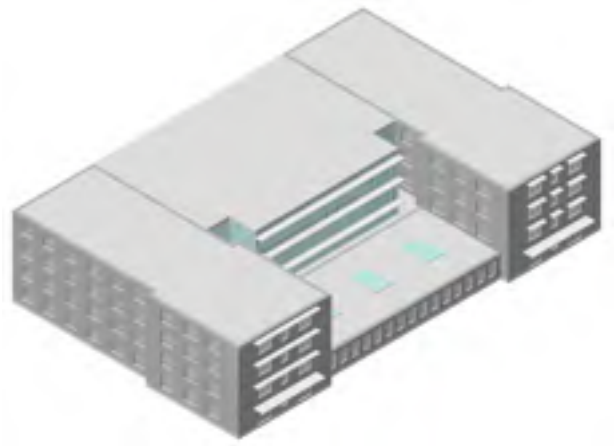
Virtual Project Data Integration Testbed – AECOO Collaboration

Identified Major Gaps in Measurement Science and Information Standards for Multidisciplinary Collaboration to Improve Building Energy Performance



Demo Test Model Description:

- Simplified GSA 1800 F St. building
- 4 floors
- 4 story atrium
- Use of virtual space boundaries



Baseline BIM

Reduce all window sizes by 25%

Add overhangs on south and west facade

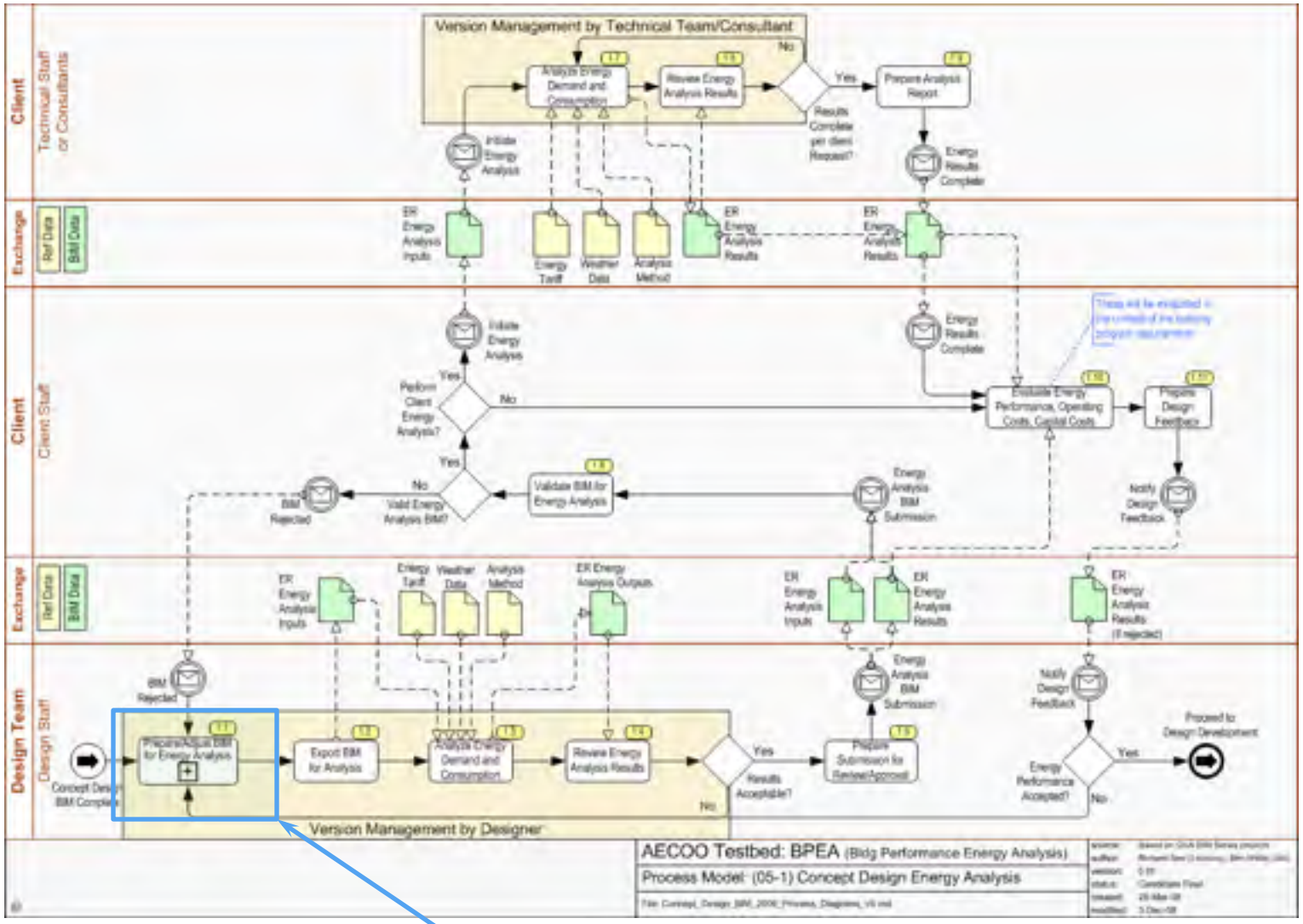
Change glazing type

Change roof construction type

AECOO Testbed – Industry and Government Partnership

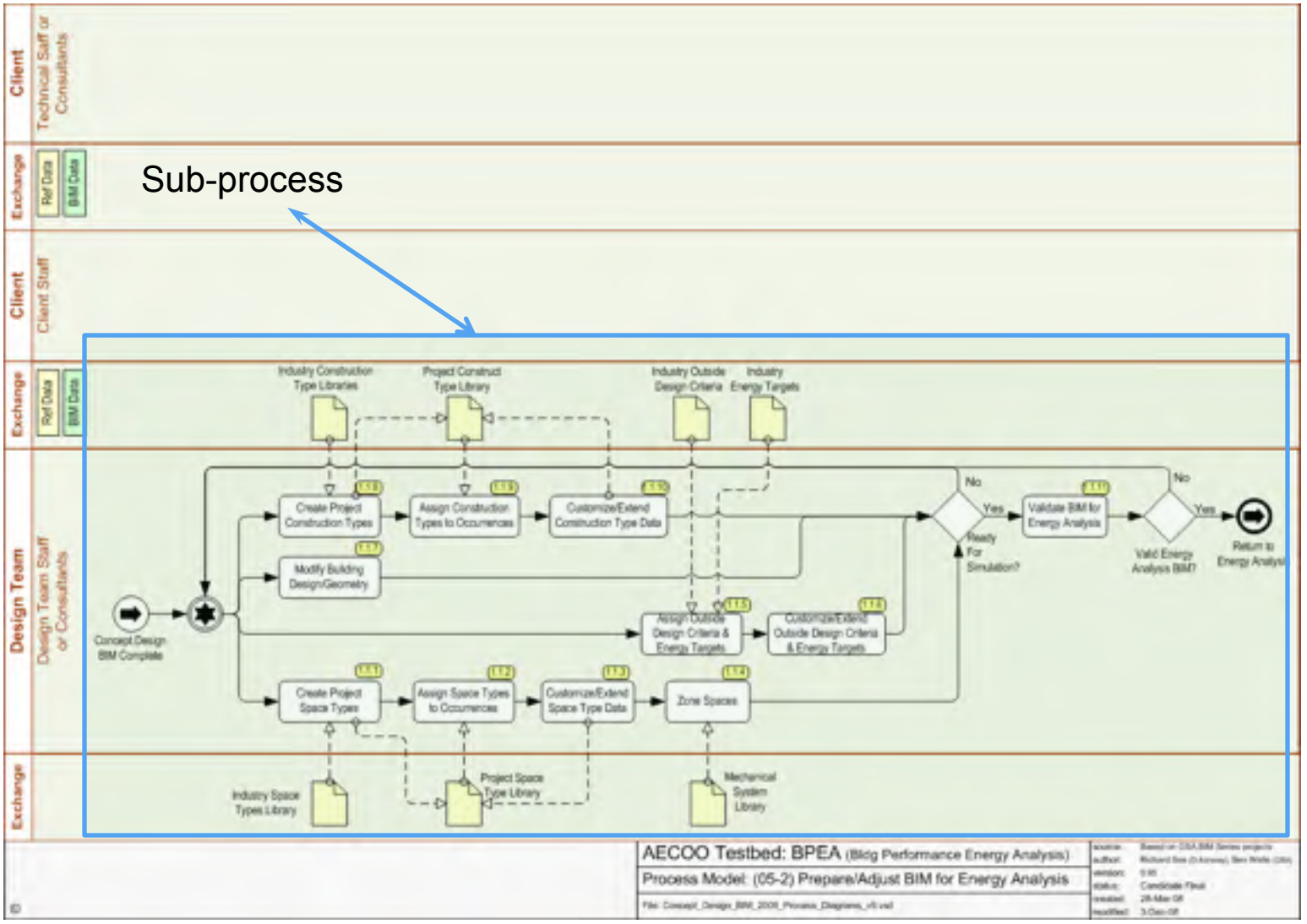
Demonstrated at the National Building Museum and in webinars, March-May 2009

BPEA IDM- Process Model



Sub-process

BPEA IDM- Process Model (cont'd)



Industry Data Sources for Space/Construction Types

GSA Star Space Type	ASHRAE 62.1	Title 24 CA Energy Code	ASHRAE 90.1	Lighting Power Density [W/ft2] (90.1)	Lighting Power Density [W/ft2] (Title 24)	Occupant Density (people/1000 ft2) (Title 24)	Sensible Heat/person [Btu/person]	Latent Heat/person [Btu/person]	Equipment Power Density [W/ft2] (Title 24)	OA Requirements [cfm/ft2] (Title 62.1)
Office	Office Space	Office	Office-Enclosed	1.1	1.2	10	245	200	1.5	0.15
Open Office	Office Space	Office	Office-Open Plan	1.1	1.2	10	245	200	1.5	0.15
Conference	Conference/Meeting	Convention, Conference, Multipurpose and Meeting Centers	Conference/Meeting/Multipurpose	1.3	1.4	47	245	155	1	0.5
Classroom	Lecture Classroom	Classrooms (Lecture, Training, Vocational) Room	Classroom/Lecture/Training	1.4	1.2	50	245	155	1	0.18
Classroom	Lecture Classroom	Classrooms (Lecture, Training, Vocational) Room	For Penitentiary	1.3	1.2	30	245	155	1	0.18

Sources of Space data: ASHRAE 90.1, ASHRAE 62.1, Title 24
Space classifications: GSA Star Space Type, Omniclass Table 13, IBC, IECC

Wall Type	Wall Number	Wall Number Descriptions	Layer ID (Outside to Inside)							
Curtain Walls	1	Spandrel glass, R-10 insulation board, gyp board	F01	F09	F04	I02	F04	G01	F02	-
Curtain Walls	2	Metal wall panel, R-10 insulation board, gyp board	F01	F08	F04	I02	F04	G01	F02	-
Curtain Walls	3	1 in. stone, R-10 insulation board, gyp board	F01	F10	F04	I02	F04	G01	F02	-
Stud Walls	4	Metal wall panel, sheathing, R-11 batt insulation, gyp board	F01	F08	G03	I04	G01	F02	-	-

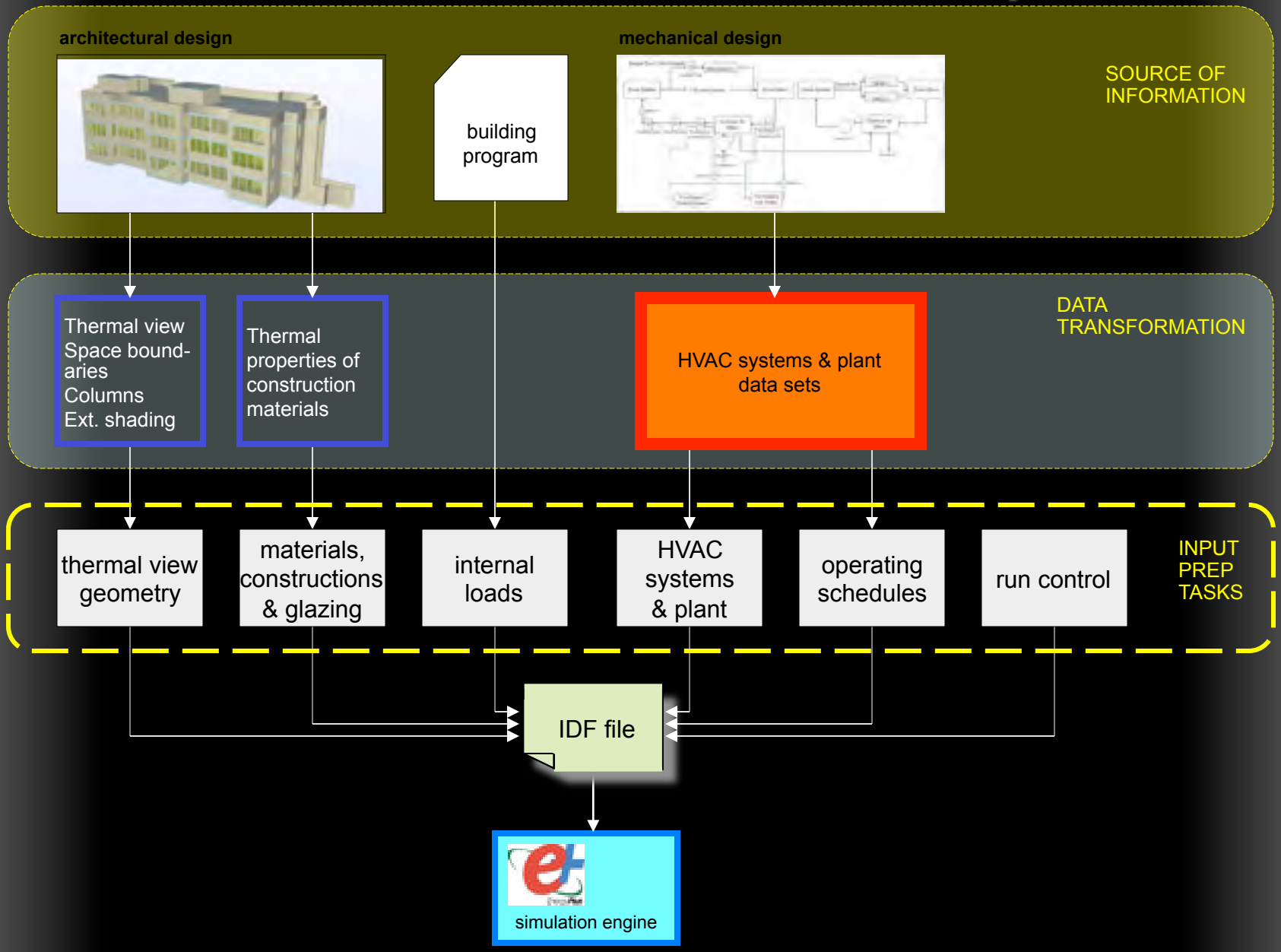
Roof Type	Roof Number	Roof Number Descriptions	Layer ID (Outside to Inside)							
Sloped Frame Roofs	1	Metal roof, R-19 batt insulation, gyp board	F01	F08	G03	F05	I05	G01	F03	-
Sloped Frame Roofs	2	Metal roof, R-19 batt insulation, suspended acoustical ceiling	F01	F08	G03	F05	I05	F05	F16	F03
Sloped Frame Roofs	3	Metal roof, R-19 batt insulation	F01	F08	G03	F05	I05	F03	-	-
Sloped Frame Roofs	4	Asphalt shingles, wood sheathing, R-19 batt insulation, gyp board	F01	F12	G05	F05	I05	F05	G01	F03

Opaque Construction Source: ASHRAE Fundamentals Tables 17, 18, 19

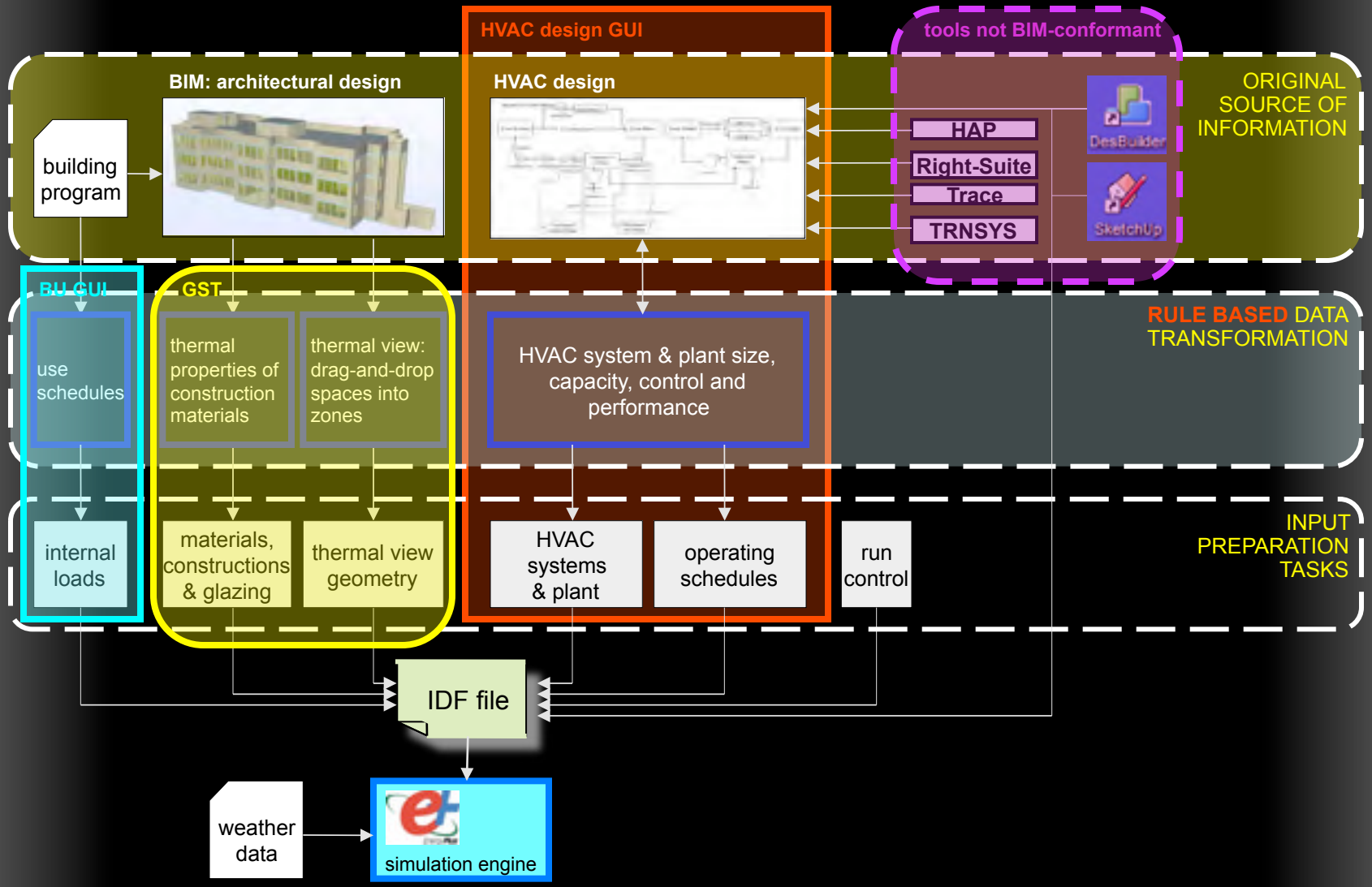
1. In the process of mapping 90.1, 62.1, Title 24, and GSA Star Space Type. Will working with CEC and ASHRAE. ASHRAE contact? Ask Krishnan.
2. CSI and ICC almost done with version 1 of Omniclass mappings. Will be integrated when complete.
3. Space and construction tables will be provided to vendors to enable within their application. Selection of which defaults to use when multiple?
4. Select the final constructions. Need overhang construction.

OGC

BEP Simulation Data Components

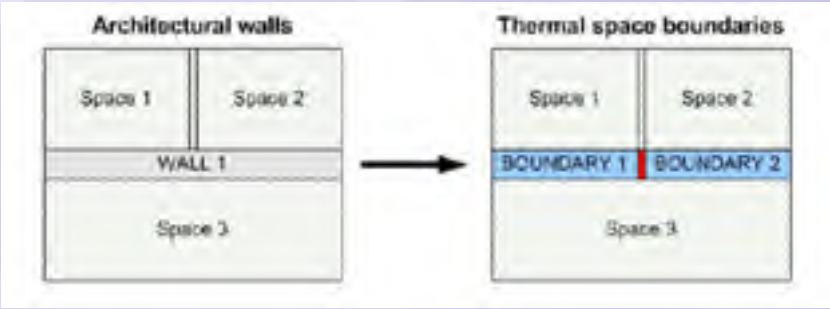


BEP-BIM Simulation Environment



Identified Problems

- Lack of consistent vocabularies, even in the same discipline, e.g., ASHRAE standards
- Marginal understanding of the assumptions and constraints
- Traceability for ensuring fidelity of simulation models and conclusions is missing
  - How many “certified” high-performance buildings perform as promised?
- Fundamental concepts for thermal and multi-system modeling are not supported or understood by software tools or users
  - 2nd level space boundaries



Research Challenges

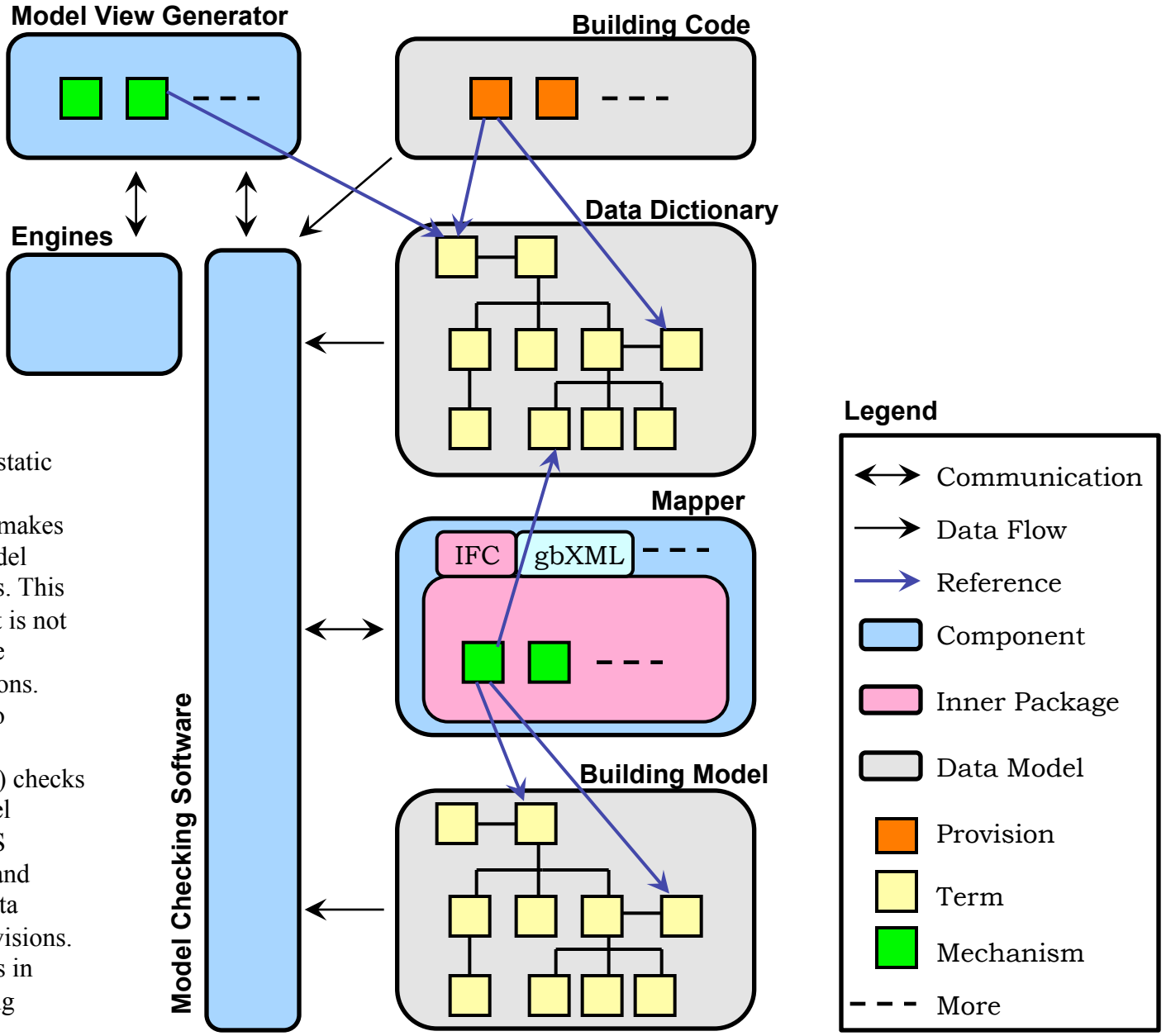
Change is underway.

- GSA: requiring building information models (BIM)
- CEC, CMU and others working on fundamentals for “processable” standards
- Contractors automating processes =>. new business models: CIS/2, agcXML
- ASHRAE: migrating to a unified data dictionary for processable standards
  - ASHRAE BIM Guide
- Drive to life cycle costing, reduced energy use, sustainability, integrated ICT
  - CIB Priority: Integrated Design and Delivery Solutions (October 2009)

Challenges

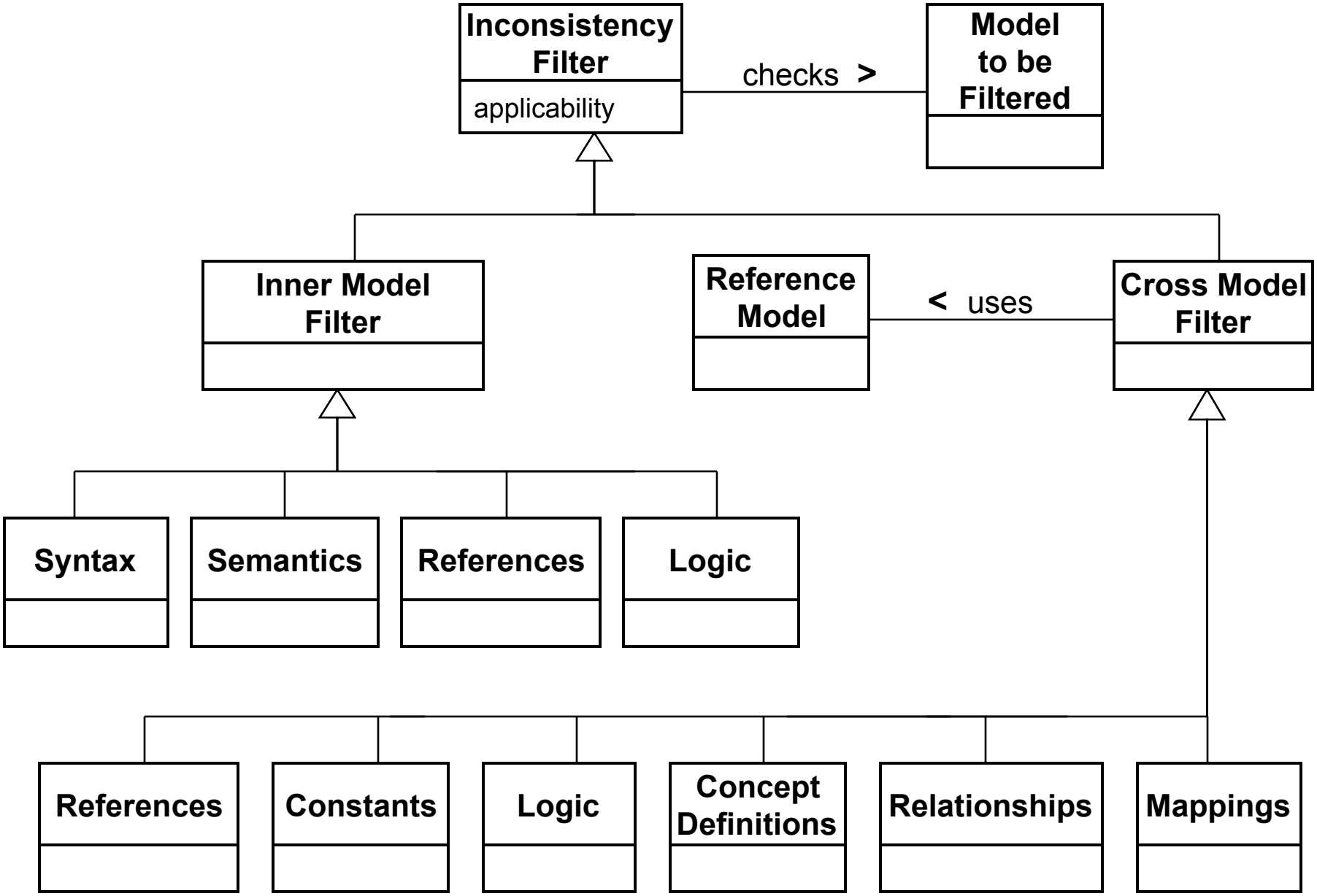
- Work process innovation vs sub-optimization
- Multidisciplinary collaboration with life cycle perspective
- Accurate simulation models, e.g., energy
- Information modeling, interoperability, systems integration
- Standard terminology for content and session messaging
- Collaborative management of shared virtual models
- Extensible code compliance checking
- Building the semantic foundation for federated information resources

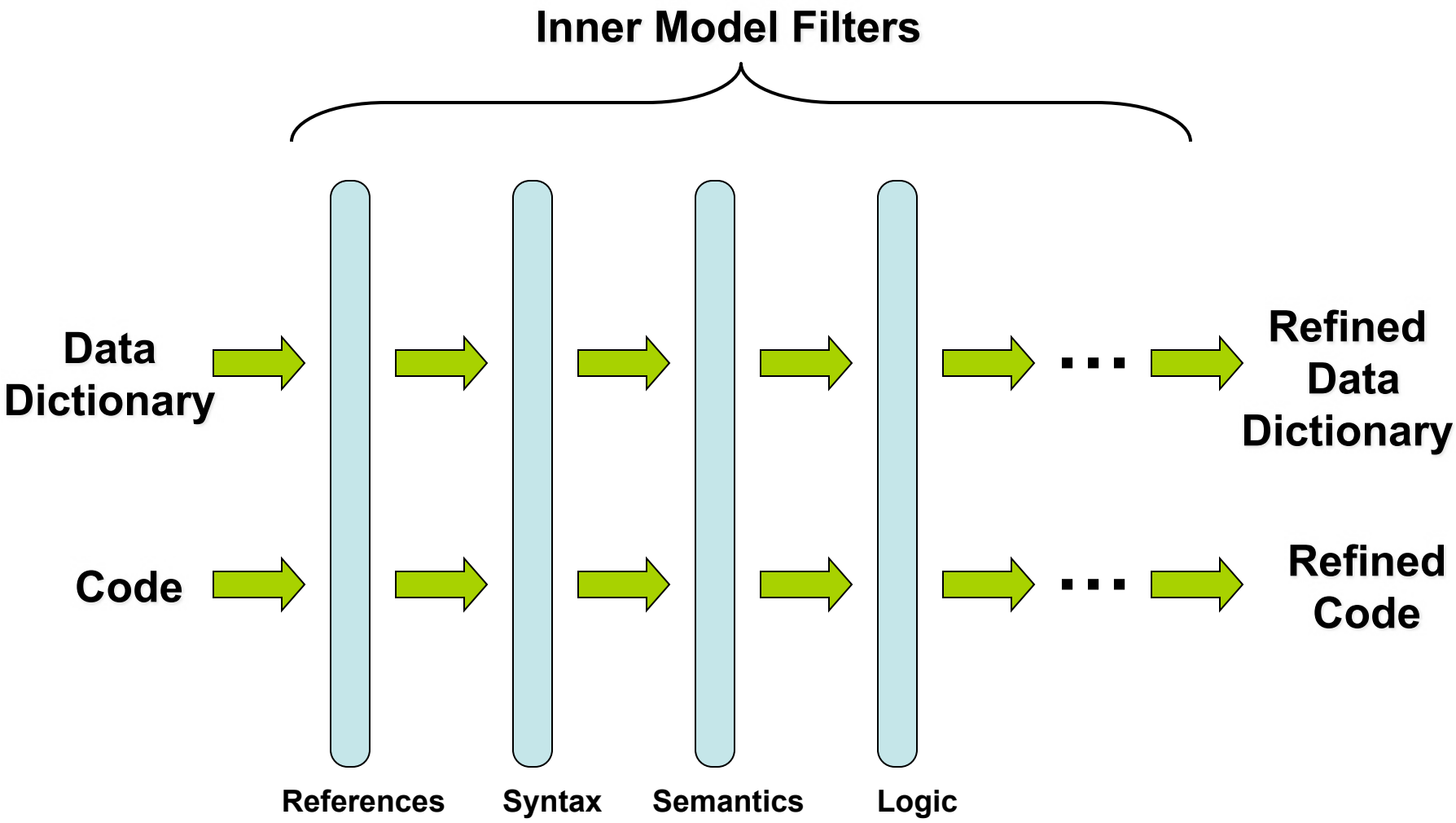
Automated Code Checking Framework

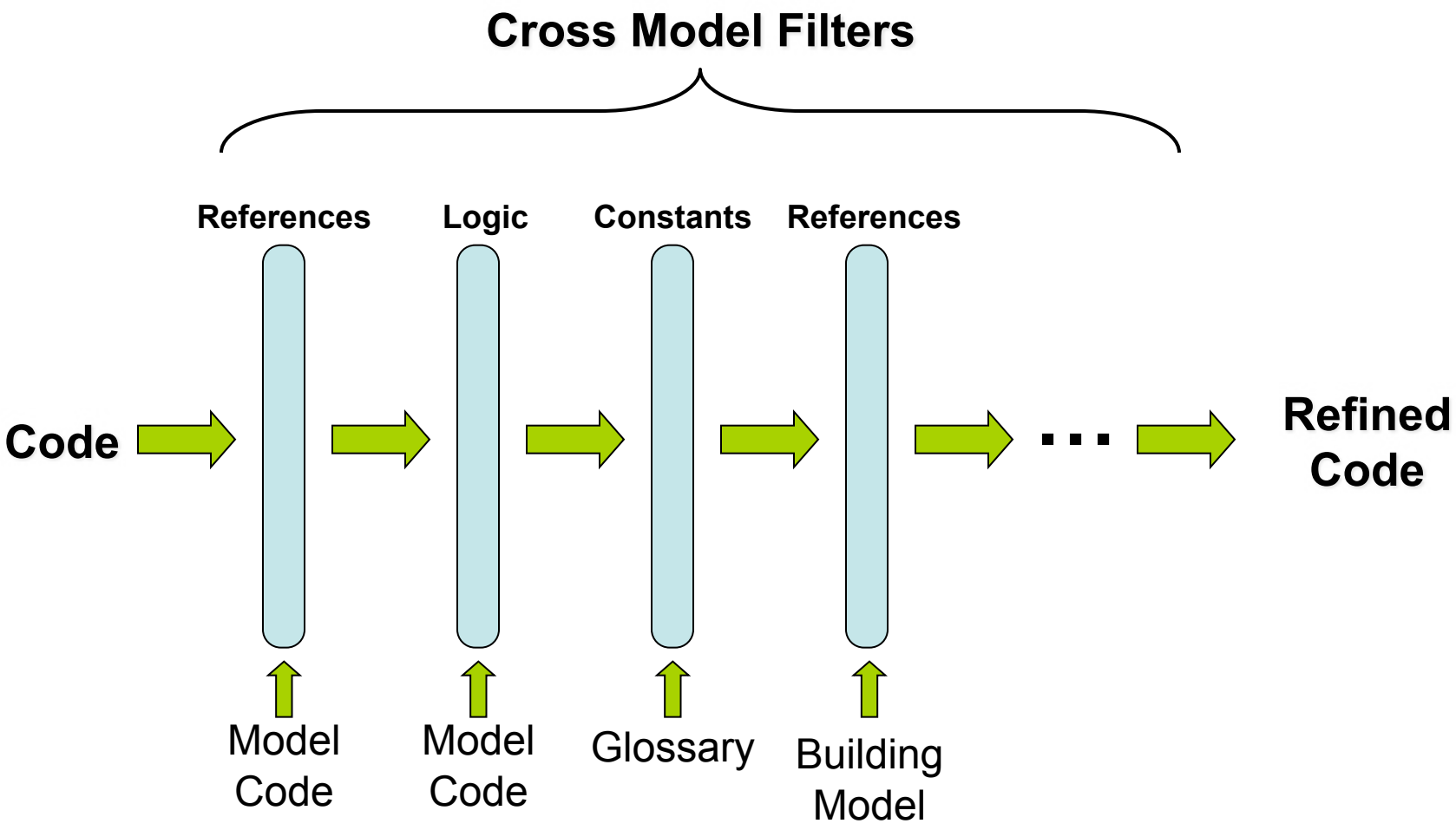


-Notes:
- Data models do not contain a reasoning mechanism. They are static components of the system
Model View Generator (MVG) makes inferences from the building model required by data dictionary terms. This view consists of information that is not able to be taken directly from the building such as energy simulations. MVG utilizes external engines to perform view generation.
Model Checker Software (MCS) checks compliance of the building model according to building code. MCS communicates with the mapper and MVG in order to interpret the data dictionary terms in the code provisions.
- Mapper consists of many layers in order to support different building modeling representations

Classification of Filters




Inner Model Filters
Data Dictionary
Code
References
Syntax
Semantics
Logic
Refined Data Dictionary
Refined Code


Cross Model Filters
References
Logic
Constants
References
Code
Refined Code
Model Code
Model Code
Glossary
Building Model

Reference Information Models for Integrated Building Energy Analysis and HVAC Design

Problem

Current practices and measurement science are inadequate, cumbersome and do not integrate effectively to address the new requirements for achieving significant improvements in building energy performance

Objective

- Develop reference information models and alignment mechanisms for:
  - Building envelop
  - Building thermal model
  - Building systems, e.g., HVAC, energy management, plug loads
  - Mechanical equipment
  - Project information QC
- Demonstrate value of data dictionaries, processable standards and rule editors for achieving 21st century building engineering and code compliance

Approach

- Collaborative project – building the team now
  - ✓ ASHRAE, LBNL, PNNL, CMU, NIST
- Analyze current tools, dictionaries and reference models
- Develop example solution for selected use cases
- Develop tools and recommendations for standards development, e.g., ASHRAE, NBIMS

Building Environment Division Advertised Positions

1. Information Systems for Engineering and Construction
2. Evaluation of Alternative HVAC&R Technologies
3. Performance Characterization of Photovoltaics and Energy Monitoring
4. Building Envelop Airtightness and Thermal Integrity
5. Technology and Standards for Building Systems Linkage to Smart Grid